The Botrychiaceae of Alberta

a survey of element occurrences of the genera Botrychium and Sceptridium in Alberta

A Report by
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To

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THE BOTRYCHIACEAE OF ALBERTA

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Botrychium 'michiganense'

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INTRODUCTION

With 14 listed species, the moonworts, those ferns belonging to the genus *Botrychium*, are the largest group of rare ferns in Alberta (Gould 2001). This group has appropriately attracted the attention of organizations and government agencies responsible for maintaining biological diversity, both within the province and abroad. With a view to assessing the conservation status of the moonworts, Alberta Sustainable Resource Development funded the publication of a small book that addressed the taxonomy and distributional ecology of these ferns within Alberta (Williston 2001). In the adjacent United States, rare *Botrychium* species have been the focus of no fewer than six recent reports and conservation strategies (Zika 1994; Zika et al. 1995; Vanderhorst 1997; Hopkins 1999; Farrar 2001; Kolb & Spribille 2001).

In 2001, a project was initiated by Alberta Sustainable Resource Development to identify potential threats to these species and their habitats in Alberta. The objectives of the project were to revisit known populations of rare *Botrychium* species, search for new populations, document (using photographs and Vegetation Description Forms) the characteristics of their habitats, and evaluate potential threats to their security. A synthesis of the data collected during this project is presented in this summary report.

METHODS

A list of all historical locations of *Botrychium* populations based upon herbarium collections and additional records from the provincial rare plant database was obtained from the Alberta Natural Heritage Information Centre (ANHIC). Sites were revisited with priority placed upon those species ranked S1 or S2 (Gould 2001). In particular, priority was given to the following species: *B. ascendens* (S1), *B. campestre* (S1), *B. crenulatum* (S1), *B. lanceolatum* (S2), *B. pallidum* (S1), *B.* 'michiganense' (S1), *B. minganense* (S2S3), *B. paradoxum* (S1), *B. pedunculosum* (S1), *B. pinnatum* (S1), *B. simplex* (S2), *B. spathulatum* (S2), *B.* x *watertonense* (S1), and *Sceptridium multifidum* (*B. multifidum*; S2). Not all locations were visited; several were too remote to access within the time allotted to this project.

For each site, a vegetation description for a 10m radius circle was completed using percent cover estimates for the dominant species. Cover estimates were recorded for mineral soil, total vegetation cover, litter, moss, and lichen. Slope, aspect, elevation, legal location, and UTM coordinates were also recorded and entered onto Vegetation Description Forms and Rare Native Vascular Plant Report Forms. When available, airphotos were used to mark the precise location of each site. The number of *Botrychium* plants per species was counted or estimated at each site and potential threats to habitats were identified. Suitable habitat surrounding each previously established site was examined for additional populations. Nearly 40 herbarium specimens were prepared from samples of several populations. These have been submitted to Alberta Sustainable Resource Development to be deposited in the University of Alberta Herbarium and represent a significant addition to the University's current collection. Photographs of each

species and its habitat were made using a standard 35mm SLR camera. These photographs and report forms have been submitted to Alberta Sustainable Resource Development.

Taxonomy follows Williston 2001 and reflects the nomenclature currently being used by plant taxonomists in North America (F. Wagner pers. comm.), Japan (Nakai 1949; Sahashi 1979), and Europe (Holub 1973). There are two differences from the names used in the 'Flora of Alberta' (Moss 1983): (1) the Botrychiaceae is recognized as a family that is distinct from, though related to, the Ophioglossaceae; (2) *Sceptridium multifidum* (*Botrychium multifidum*) and *Botrypus virginianus* (*Botrychium virginianum*) are separated at the genus level as being distinct from the other *Botrychium* species.

This survey included the genus *Sceptridium* because of its association with the genus *Botrychium* and because it is frequently found in mixed populations with *Botrychium* species. Furthermore, *Sceptridium* is commonly grouped into *Botrychium* in lists and publications such as the ANHIC list of the rare plants of Alberta (Gould 2001).

SUMMARY OF HABITAT CHARACTERISTICS

The distributions of moonworts are dependent upon at least two factors: the availability of appropriate habitat and the ability to get there (dispersion). Moonwort dispersal has been treated only summarily in most reports (and in this one as well). There has been, however, much discussion about the characteristics of their habitats (Zika 1994; Zika et al. 1995; Vanderhorts 1997; Kershaw et al. 2001; Kolb and Spribille 2001; Williston 2001).

Moonwort spores are very small and easily transported by wind and so dispersion is not believed to limit moonwort distributions, at least locally (Kolb & Spribille 2001). Moonworts are primarily self-fertilized and outcross less than 1% of the time (Farrar 2001). This results in spores that are identical clones of the parent plant. Thus, small populations can become established from a single successful spore, but contain essentially no genetic variation. More common are mixed populations with multiple species and several independently established genetic isolates of each species with little or no genetic exchange.

On a broader scale, events like the glaciation of northern North America, landforms such as the Rocky Mountains, and the direction of prevailing winds may influence the distributions of even very small spores, and certainly those of moonworts. Moonwort distributions have yet to be examined in the context of these broad-scale factors, perhaps due to the historical paucity of collections.

Characterizing moonwort habitat is difficult, in part because of the inherent secrecy of the gametophytic life history stage of these ferns. Moonwort gametophytes are subterranean and their ecology has largely eluded precise description. While the gametophyte is known to require the association of endophytic fungi, the requirements and the distributions of

the fungi involved in this relationship remain a mystery. It is possible that the interactions among moonworts and fungi are responsible for the irregular distributional patterns we see among moonworts in seemingly uniform habitats (Kolb & Spribille 2001).

Previous studies have made a number of generalizations about habitats that can be applied to Alberta's species. Most species appear to rely upon habitat dynamism and proliferate on substrates that have been disturbed within the last 50 years (Kolb & Spribille 2001). These habitats are found in areas with natural disturbances such as slope failures, sand dunes, riverbanks, flood plains, avalanches, wildfires, and disturbed areas created by wildlife such as herds of bison. Because of a variety of human interventions such as dykes, dams, fire suppression, and the dramatic reduction of wildlife herds, many of these disturbances are not as prevalent as they once were. Since European settlement, early successional, anthropogenic habitats have become increasingly common and several of these habitats, such as old trails, roads, cutbanks, abandoned agricultural fields, and rangelands, have been found to support moonworts.

As our human population grows, so too do the number of anthropogenic habitats. Correspondingly, the number of moonwort populations should be expected to increase (Kolb & Spribille 2001). This trend is difficult to substantiate given the lack of historical, pre-disturbance data. The number of specimens contributed to herbaria has increased with time, but this is probably a function of an increase in awareness rather than an increase in true abundance. Obviously, not all anthropogenic habitats harbour moonworts; in fact, among Alberta's rarest moonworts is *B. crenulatum*, which is only known from natural habitats within Alberta. This suggests that it is not possible to rely upon anthropogenic disturbances for the preservation of all rare moonworts. To ensure the existence of some rare species, the processes that create natural disturbances need to be maintained, and that requires preserving ecosystem integrity.

Zika (1994) calls plants that require early seral habitats, "fugitives of succession" because, as a plant community develops over time, many of the early seral plants are unable to persist and need to disperse to more recently disturbed substrates. Moonworts are not the only fugitives of succession; several of Alberta's rare plants are also adapted to early seral conditions for example *Erigeron flagellaris*, *Brickellia grandiflora*, and *Thelesperma subnudum* var. *marginatum* (Kershaw et al. 2001).

By examining the information gathered on the vegetation description forms (submitted to the Resource Data Division) it is possible to make a few generalizations about the habitats of *Botrychium* species within Alberta. The range of conditions where they can be found is remarkable; from more or less barren soil to dense graminoid meadows; from undifferentiated sandy substrates and recently deglaciated till to well developed horizonated soils; from xeric to subhygric soil moisture regimes; and from sites with either anthropogenic or natural disturbances. This suggests that moonworts should be widespread and common, which is not the case; while a few species are widespread, none are common.

In Elk Island National Park, sandy substrates are the preferred habitats of moonworts. Herbarium collections indicate that other sand hills in central and eastern Alberta also harbour *Botrychium* species. Clay-based soils, which are more prevalent than sandy soils within the Park, did not appear to support moonworts (G. Griffiths pers. comm.). Populations in the Rockies and Foothills Natural Areas tended to be situated on coarse textured soils that varied in development from regosols at higher elevations (>1800m) and along a number of old roads, to horizonated brunisols at middle to high elevations (1370-1800m).

The slopes of *Botrychium* localities were generally below 10%, though a few sites in the Rocky Mountains had greater values (Appendix A). All aspects were represented; however, low slope values tend to reduce aspect effects and so an aspect preference was not expected. Soils moisture was most commonly subxeric to submesic with a small number of both wetter and drier sites. Ground cover attributes were highly variable. Moonwort sites had a mean cover of vascular plants close to 40%, while the means for exposed soil, litter, and mosses were between 25 and 30%. The mean lichen cover was lower at about 12%. Most sites had at least some bare soil or some sign of historical or recent disturbance, either natural or anthropogenic. Zika (1994) suggested that moonworts inhabiting densely vegetated areas represent plants that originally colonized the site after a disturbance event, when competition was lower. Several species bear asexual gemmae from the bases of their stems, which may allow them to persist under densely vegetated conditions that would otherwise prevent the germination of spores and the development of subterranean gametophytes.

There are several plants that are frequently associated with moonworts (Appendix A). These plants are early successional species and most respond positively to soil disturbance. They are also more common than moonworts, and many locations that bear these associates do not support *Botrychium* species. Conversely, most *Botrychium* sites have at least a few of the associated species. *Fragaria virginiana* is a common and widespread plant that is nearly always present at *Botrychium* sites within Alberta and elsewhere. *Gentianella amarella*, *Equisetum arvense*, and *Achillea millefolium* are also common in *Botrychium* locations. *Campanula rotundifolia* and *Penstemon confertus* (*Penstemon procerus* is a common associate in British Columbia) are frequent associates in their respective ranges. *Allium cernuum*, *Galium boreale*, *Potentilla gracilis*, and *Rhinanthus minor* are occasionally abundant at moonwort localities, though not as regularly as those species mentioned above.

In summary, because many *Botrychium* species are able to colonize sites with anthropogenic disturbances, and because these disturbances are continually increasing in prevalence, the availability of suitable habitat may not be limiting the distribution of most moonworts. In fact, we should expect the numbers of populations to increase. Furthermore, because their spores are very small and easily transported by wind, dispersion should not be limiting either. The question remains, why are these ferns so rare? The answer is not known, but may relate to the dependence of these ferns upon endophytic fungi for gametophytic survival. The relationships between the ferns and the fungi are poorly understood, and the habitat requirements, reproduction, and dispersion of the fungi lack sufficient study. Until we understand the limitations of their distributions, it is necessary to protect populations of rare moonworts where we know them to exist.

CONSERVATION STRATEGIES

Many new moonwort localities were documented during the field survey portion of this project. This appears to confirm the suggestion that most *Botrychium* species are more common than their historical collections might otherwise indicate. However, only two new locations were discovered among the rarest of these ferns (*B. campestre* in South Drywood Creek and *B. pallidum* in Elk Island National Park). This survey did not encounter new populations of *B. crenulatum*, *B. paradoxum*, or *B.* x *watertonense* (though in July 2001, botanists from the Alberta Natural Heritage Information Centre [ANHIC] discovered a population of *B. crenulatum* near La Butte; K. Vujnovic pers. comm.; confirmed by P. Williston), which suggests that several species are truly rare and not merely overlooked. Undiscovered populations of these rare plants undoubtedly exist, but until they are found, these species must retain their threatened status. The discovery of a population of what may prove to be a new species of *Botrychium* in Elk Island National Park emphasizes that our understanding of moonwort taxonomy is still incomplete.

There are two broad threats to moonworts and their habitats: 1) infilling of grasslands by trees and shrubs, possibly exacerbated by fire suppression; and 2) residential, recreational, and commercial development of natural lands. A broad-scale conservation strategy needs to recognize these two threats. The first type of threat is most common in national and provincial parks, and on Crown Land. The second threat is more common on private lands but may also occur in parks and on other public lands.

The first threat, infilling, can be addressed with two complementary approaches. Most parks have fire management plans that include prescribed burn programs. If well researched and fully implemented, fire management plans could be the first approach to maintaining natural grassland openings, the types of habitats where moonworts occur. When possible, pre- and post-fire vegetation data should be gathered to document how prescribed burns affect native vegetation. The second approach is to specifically target the locations of threatened populations that are experiencing declines due to tree or shrub encroachment. This may only be necessary for those species that are known from three or

fewer populations within Alberta. Because these species are so rare, and because the effect of fire on moonworts is still poorly understood (there are two reports of moonworts emerging in large numbers after fire; Hopkins et al. 1999; Sessions and Kelly 2001), this approach must only be used in situations where there is sufficient monitoring data to suggest that the target population will be extirpated if actions are not taken.

The second threat, the conversion of natural lands into developed areas, includes agricultural fields, residences, commercial and industrial complexes, and even park infrastructures such as campsites. This threat can also be addressed in two ways. The first is to hire professional biologists to survey proposed development lands prior to excavation or site modification. This is especially important in lands near known populations of rare species of moonworts, other vascular and non-vascular plants, mammals, insects, or any other rare organisms. The second is to raise awareness within the botanical community, and the public at large, about the loss of habitat and the habitat characteristics of rare species. This approach has been partially fulfilled with the publication of "The Botrychiaceae of Alberta" in the spring of 2001, and even more recently with "Rare Vascular Plants of Alberta", a book by the Alberta Native Plant Council. Both of these books were published with the support of Alberta Sustainable Resource Development.

Most of the *Botrychium* species known to occur in Alberta are not likely to become extirpated, at least not in the near future; however, it is not possible to predict whether these species will survive the predicted climatic changes associated with global warming. Many of the populations within Alberta are peripheral, meaning they are on the edge of the species' ranges. Such populations are hypothesized to contain genetic variation that may be key to the adaptation of these plants to the changing conditions expected in the future. In essence, every population is added insurance against the possibility of future extinction.

There are six species known from three or fewer populations with short-term security that is less assured, and in some cases, possibly threatened. Consideration should be made for preparing conservation management plans for these six. Three of these rare species, *Botrychium* x *watertonense*, *B. paradoxum*, and *B. pedunculosum*, which occur together in mixed populations, could be addressed in a single plan. *B. campestre*, *B. pallidum*, and *B. crenulatum*, which have varied distributions, require separate plans.

The highest priority should be allotted to securing the populations of *Botrychium campestre*, *B. paradoxum* and *B.* x *watertonense* in South Drywood Creek. These populations are internationally significant and are presently exposed to a range of resource uses including recreation, gas exploration, and livestock grazing. The population of *B. campestre* is believed to be the westernmost in the world and represents the second extant population known in Alberta (a third population near Fort Saskatchewan is believed to be extirpated). *B. paradoxum* is globally rare (G2) and is known from only two other localities in Alberta, while *B.* x *watertonense* is rated G1 and known from only three populations in the world (Williston 2001).

MANAGEMENT RECOMMENDATIONS

Management recommendations are made for eight general regions that were visited during the 2001 field season. For practical reasons, and also due to time constraints, not all areas of the province were surveyed. Suggestions are made for future investigations in four regions that are suspected of containing important populations of *Botrychium* species.

Elk Island National Park

This park contains several significant populations of rare *Botrychium* species. It also contains large numbers of bison, moose, deer, and elk that are, in part, responsible for creating habitat that is favourable to these rare ferns. Another habitat feature is the park's sand dunes. Near the eastern edge of the park there is a region where aeolian sand dunes once developed at the edge of an ancient lake. These sandy substrates drain rapidly and support xeric and subxeric plant communities. They occur on the tops of knolls and low ridges where they cover, with varying thickness, a clay dominated soil horizon that is less pervious and that supports moist forests, ponds, and wetlands. The sandy knolls and ridges are the preferred substrates for a large number of *Botrychium* species. They are most noticeable along the edges of game trails, park user trails, and old access roads, all of which are maintained as shrub-free by the persistent browsing and grazing of bison, moose, deer, and elk. Moonworts also occur in natural openings such as grasslands and herb meadows, places where bison tend to wallow.

Botrychium 'michiganense', *B. minganense*, *B. pallidum*, *B. pinnatum*, *B. simplex* and *Sceptridium multifidum* tend to prefer xeric to subxeric sites within the park while *B. lanceolatum* and *B. ascendens* are more frequently found on submesic to mesic sites. This pattern does not necessarily hold true for other localities, for instance *B. lanceolatum* and *B. ascendens* are found in much drier sites in the Rocky Mountains Natural Region. Visits to Elk Island during June, July, and August resulted in 6 additions, all *Botrychium* species, to the vascular plant species list compiled by Graham Griffiths and Patsy Cotterill (2001).

There are no perceived threats to these populations. Infilling by shrubs and aspen trees does not appear to be a problem, though annual surveys may be the best way to determine if the populations are stable. Because the park is situated in a transition zone between the Boreal Forest Natural Region and the Aspen Parkland Natural Region, the natural fire cycle is probably somewhat longer than typical parkland ecosystems. This should be reflected in the prescribed burning policy of the park. Most of the known localities are rarely used by park visitors and are only occasionally visited by knowing botanists. Because the sites are close to Edmonton and are well known to ANHIC botanists, these plants may be good candidates for

Botrychium 'laciniatum'

long-term research such as influences of drought on dormancy, or patterns of recruitment and longevity.

Of special concern are the populations of *Botrychium pallidum*, which are the only known ones in Alberta. These plants are common in the sand hills portion of the park, but are not found elsewhere. Park managers need to be aware of the significance of these populations. Also notable is the collection of a number of peculiar specimens that may, in fact, be a new species, and called here *Botrychium* 'laciniatum'. This tentative species was collected in two localities, ELK 4 and ELK 7, approximately 3.7 km apart from one another. Further collections may be required for isozyme or DNA analysis to determine if they represent an undescribed species.

Species of concern:

Botrychium ascendens	northernmost and easternmost population in Alberta
Botrychium 'laciniatum'	may be a new species but requires further study. Material will be required for DNA analysis
Botrychium lanceolatum	easternmost population in Alberta
Botrychium 'michiganense'	known from only 4 other localities in Alberta including a new location discovered by ANHIC botanists (among them Ksenija Vujnovic and Lorna Allen) in 2001
Botrychium minganense	known from more than 10 localities
Botrychium pallidum	perhaps the westernmost population in the world and the only known locality in Alberta
Botrychium pinnatum	easternmost population of this plant in Alberta
Botrychium simplex	known from only 4 other localities in Alberta including a new location discovered by ANHIC botanists (among them Ksenija Vujnovic and Lorna Allen) in 2001
Sceptridium multifidum	known from more than 10 localities

Waterton Lakes National Park

The primary *Botrychium* sites of concern in this park are in the Red Rock Canyon area. A number of the pocket grasslands, small patches usually less than 1 ha in size, along the Snowshoe Trail contain populations of globally rare *Botrychium* species. One of these sites, about 800 m northwest of the parking area, is the type locality of *Botrychium* x *watertonense*. Only 200 m from the parking area is the site used by Peter Lesica and Kathy Ahlenslager for their long-term *Botrychium* life history study (Lesica and Ahlenslager 1996). The principal conservation concern in these sites is infilling by aspen and pine trees, and the accumulation of vegetative litter in the absence of fire. Fire suppression may be contributing to this successional process and appears to be having a negative influence on the habitat of these rare ferns. Long-term monitoring of these *Botrychium* populations and documentation of the infilling of their habitat is strongly recommended. Other rare plants such as *Allium geyeri* also occur in these high elevation grasslands and may similarly be susceptible to habitat loss due to tree encroachment. The fire management plan for the park needs to recognize the value of maintaining these grasslands and the use of prescribed burning should be evaluated.

Though the canyon itself draws thousands of visitors every year, the activities of tourists are mainly restricted to the creek and the trails, and do not appear to affect moonwort populations. The only possible exception is recreational horse riding. In the interest of preventing the introduction of exotic invasive plants, horses should be restricted to the main trails and riders should be strongly encouraged to keep their animals off the grasslands in the Red Rock Canyon area. Even though one of the *Botrychium* locations is thought to have been used as a horse staging area in the past (the site closest to the parking area), the rarest species are still potentially vulnerable to unintentional extirpation if grazing is permitted for domestic animals.

Species of concern:

Allium geyeri	S2, restricted, within Alberta, to the southwestern corner
Botrychium 'michiganense'	may be the westernmost population in the world
Botrychium minganense	known from more than 10 localities
Botrychium paradoxum	known from only two other localities within Alberta, both in the southwest
Botrychium pedunculosum	the only known population in Alberta
Botrychium x *watertonense*	one of two populations known in Alberta, and of three in the world (the third is in Montana)

South Drywood Creek

Situated north of Waterton Lakes National Park, the high elevation watershed of South Drywood Creek contains a wealth of rare ferns and is biologically extremely rich. The southwest corner of Alberta supports the greatest number and the highest concentrations of rare plants in the province so it is not surprising that South Drywood Creek should harbour several of them.

South Drywood Creek is presently used for a number of industrial and recreational activities. The east end of the valley contains a number of gas installations and there is a gas exploration road that climbs up the valley floor to a small, high elevation lake at the west end. This road is used for recreation such as four-wheel driving, hiking, and hunting. The lower valley and foothills, particularly along the banks of South Drywood Creek, are used for informal summer camping and for driving off-road vehicles.

The mid and upper valley, beyond the last gas installation, is used as pasture by commercial livestock. The effect of this livestock on the rare plants of the valley is not known, but their influence on the vegetation is pronounced, especially in areas where they dwell for long periods of time. The cattle are, in part, responsible for the introduction of invasive species (road development and vehicle traffic also contribute to this problem) that are having a negative impact on the native plant communities found here. But it is unclear as to whether the disturbances created by the cattle are beneficial or deleterious to the valley's moonworts. Some view the introduction of invasive and exotic species as a serious threat to rare native plants (Wallis 1987; Haber undated). For instance, a study in New Zealand reported a decline in a population of *Botrychium australe* following the introduction of an exotic grass, *Agrostis capillaris* (Sessions and Kelly 2001). The grass was discovered to provide a suitable habitat for a slug that had a selective affinity for moonworts. However, livestock also create areas of disturbed soil,

important habitat for the establishment of moonworts; and it is apparent that moonworts have persisted in South Drywood Creek after years of livestock grazing.

In 2001, a population of *B. campestre* was discovered in South Drywood Creek within 200 m of a site that had been reported in 1999 to support *B. paradoxum* and *B.* x *watertonense* (J. Gould pers. comm.). These populations are globally significant, representing important range extensions and additional locations for very rare species. Other significant populations of rare plants have also been documented here (J. Gould pers. comm.) and it is probable that more rare species have yet to be found. A thorough botanical survey is strongly recommended. Serious consideration should be made to protect the upper portion (above the last gas installation) of South Drywood Creek. This does not necessarily mean that grazing must be prohibited, but that the effect of livestock on the populations of these plants should be determined. If further investigations show that the livestock are causing a quantifiable decline in the populations of rare moonworts, then consideration should be made for constructing exclosures to protect these plants from extirpation. Conversely, if grazing is determined to be consistent with healthy *Botrychium* populations, then this type of land use should continue.

Species of concern:

Botrychium campestre	only the third known locality in Alberta. The other two included Yamnuska and Fort Saskatchewan. The Fort Saskatchewan population is presumed to be extirpated due to railway improvements and the Yamnuska population has not been seen in subsequent years
Botrychium lanceolatum	known from more than 10 localities
Botrychium 'michiganense'	known from three other localities
Botrychium minganense	known from more than 10 localities
Botrychium paradoxum	known from only two other localities within Alberta, both in the southwest
Botrychium pinnatum	known from more than 10 localities
Botrychium x *watertonense*	the second known population in Alberta, of three known in the world
Cryptogramma stelleri	S2, known from approximately 10 localities in the Rocky Mountain Natural Region
Papaver pygmaeum	noted by J. Gould in 1999 (pers. comm.), known from approximately four localities in Alberta
Townsendia condensata	noted by J. Gould in 1999 (pers. comm.), known from approximately two localities in Alberta

Forestry Trunk Road

During the fieldwork portion of this project, several *Botrychium* populations were found along the Forestry Trunk Road, north of Coleman. The species documented among the 5 sites included *B. ascendens*, *B. lanceolatum*, *B. lunaria*, and *B. pinnatum*. The sites were

both natural (native grasslands) and anthropogenic (powerline right-of-way and an old road). Though some of these sites were subject to livestock grazing (TRUNK 1, 2, 3, and 4), and others were disturbed by informal camping and off-road vehicle use (TRUNK 4), the populations are not likely to be extirpated in the foreseeable future. This is a large region that was only superficially surveyed and yet harboured a number of interesting populations. Further investigations in this region will undoubtedly result in many more moonwort discoveries.

Yamnuska

In 1993, Peter Achuff collected a single plant of *Botrychium campestre* on an old, coarse, glacio-fluvial road in an area known as Yamnuska in the Bow corridor in the Rocky Mountain Natural Region. I revisited the location in 2001 and was unable to find any moonworts, though it was a particularly hot and dry spring which may have induced dormancy in the plants. Judging from the large spruce that was lying across the road, it does not look as though vehicles have used the road for a long time. There were, however, horses grazing nearby and horse dung in the immediate vicinity. Prior to 2001, this was only the second confirmed locality of *Botrychium campestre* in Alberta (see South Drywood Creek, above). Mike and Diane McIvor, naturalists from Banff, visit the site occasionally and may be good contacts for monitoring the site in the future.

Peter Lougheed Provincial Park

Two species, *Botrychium minganense* and *B. lunaria*, were found in four localities within Peter Lougheed Provincial Park. Three of these were situated in the large meadow beneath the park's main information centre. This meadow, which is inundated for parts of the year, contains three low mounds. The northernmost (KAN 2) and the southernmost (KAN 3) mounds harboured *Botrychiums* on their eastern flanks. The third meadow locality (KAN 1) was in the northeast corner; approximately 50m away from the information centre building and about 3m west of an interpretive sign entitled "When is a meadow not a meadow?" This third locality supported large numbers (~100 plants) of *B. lunaria*. Their proximity to a natural history trail presents a unique opportunity for an educational interpretive sign describing the folklore and ecological characteristics of moonworts. While trails surrounding the meadow are well used, the meadow itself is probably only occasionally visited. There were no perceived threats to these populations. The forth locality (KAN 4) was about 6km southwest along the park road in a small anthropogenic clearing on the roadside. This approximately 1ha clearing also supported *B. minganense* and *B. lunaria*, though in fewer numbers than the previous three sites. While I was not able to ascertain the purpose of the clearing, no threats to this population were noticed.

Castle Junction: Banff National Park

The Castle Junction Internment Camp is a well documented *Botrychium* site and was a highlight of the Botrychium Workshop in June 1999, an event led by W.H. Wagner and F.S. Wagner. This field is inhabited by hundreds of *B. lunaria* plants but also contains small numbers of *B. ascendens* and *B. pinnatum*. One specimen collected from this field is postulated to be *B. boreale*, a species otherwise known from northern Asia, Europe, and Greenland. The resemblance of the specimen to *B. pinnatum* is problematic and

conclusive isozyme or DNA evidence is still lacking. While there are no immediate threats to this site, encroachment by the surrounding pine trees may be a long-term issue. The accessibility of this site makes it a good candidate for repeated visits and yearly photographs to determine the rate of conifer encroachment; a simple, low cost research project for the National Park. Nearby, on the Castle Mountain Lookout Trail, small populations of *B. ascendens*, *B. lanceolatum*, and *B. lunaria* were found along the trailside. Though the trail receives many visitors, these populations do not appear to be threatened. Conversely, they may in fact be dependent upon the habitats created when the trail was constructed.

Icefields Parkway: Banff and Jasper National Parks

Several *Botrychium* localities were discovered along the Icefields Parkway between Castle Junction and the Athabasca Glacier, both in natural and anthropogenic habitats. The natural habitats were shrub-grassland complexes, and the disturbed sites were mainly road cutbanks and trails. Species included *B. lunaria*, *B. minganense*, *B. pinnatum*, and *B. spathulatum*. None of these populations appeared to be threatened. One of the most remarkable mixed populations found was a small number of *B. lunaria* and *B. spathulatum* plants growing adjacent to the Athabasca Glacier Trail, a trail used by thousands of visitors every year. Not only was this population notable for its proximity to a heavily used trail, but also its position with respect to the glacier (see below: Moonworts in a Recently Deglaciated Landscape).

Other Regions

Due to time constraints, the following regions were not surveyed during this project. Historical collections from these regions, or from neighbouring areas, suggest that they contain important populations of *Botrychium* species. Futher investigations are encouraged.

Jasper National Park

Botrychium species were not surveyed in the central and northern parts of Jasper National Park or the adjacent foothills in the Cadomin area. Through the collections of others, mainly Peter Achuff, it is apparent that the region has many scattered populations and reasonable abundance of promising habitat. Species known from the area include *Botrychium ascendens*, *B. lanceolatum*, *B. lunaria*, *B. minganense*, *B. pinnatum*, *B. spathulatum*, *Botrypus virginianus*, and *Sceptridium multifidum*. Though some of these species are represented by relatively few collections, they are not among the rarest of the moonworts and they are not regarded as under immediate threat of extirpation at the present time.

Northern Rockies

Though I was not able to survey the northern Rockies, Joyce Gould informed me that she made a number of *Botrychium* discoveries in the Willmore Wilderness Provincial Park during her 2001 field studies. The data that she has gathered from this area will be an important contribution to our knowledge of the distributions of these ferns.

Cypress Hills

This region is known to support a number of important botanical collections, however, the only species in the Botrychiaceae known from the Alberta portion of this area at the present time are *Botrychium minganense* (J. Gould pers. comm.) and *Botrypus virginianus* (Williston 2001). The Saskatchewan portion of the Cypress Hills has been found to support several rare species including *B. lanceolatum*, *B. lunaria*, *B.* 'michiganense', *B. pallidum*, *B. paradoxum*, *B. simplex*, and *Sceptridium multifidum* (University of Michigan Herbarium; pers. obs. 2000). These species probably also occur in adjacent Alberta but have thus far not been detected. Future investigations are recommended.

Swan Hills and Lesser Slave Lake

This area has been sparsely examined in terms of moonworts, though historical collections from here have been interesting and include *Botrychium simplex*, *B. lunaria*, *B. minganense*, *Sceptridium multifidum*, and *Botrypus virginianus*. Future investigations are encouraged.

MOONWORTS IN A RECENTLY DEGLACIATED LANDSCAPE

The discovery of a mixed population of *Botrychium lunaria* and *B. spathulatum* at the Athabasca Glacier, a popular tourist attraction within Jasper National Park, presented a unique opportunity to examine the amount of time required for two *Botrychium* species to become established in a recently deglaciated landscape. An informal survey was conducted to document the successional sequence of vascular plants after deglaciation in a space-for-time transect from the toe of the glacier to the Glacier Trail parking area.

The Athabasca Glacier has been a tourist destination for over 100 years. Since the 1800's, the recession of the glacier has been marked using date monuments; however, because the plaques that bear the dates on the monuments had been removed for refurbishing during August 2001, it was not possible to determine their dates when conducting this brief survey. Comparisons with historical photographs (Krucera 1999) were used to approximate the amount of time since deglaciation. The relative location of early seral plants are presented here in relation to the nearest monument. Monument 1 is closest to the toe of the glacier and 6 is closest to the Glacier Trail parking area.

Once the date plaques are returned, it will be a simple task to assign a more accurate date to each group of establishing plants.

Monument 1
no plants (~10 years)
Monument 2
Epilobium latifolium (~20 years)
Monument 3
Saxifraga aizoides (~25 years)
Monument 4
Dryas drummondii, *Epilobium angustifolium*, *Poa alpina*, *Minuartia rubella*, *Trisetum spicatum*, and *Salix* sp. (~30 years)
Monument 5
Festuca sp. and *Bryum* sp. (~35 years)
Monument 6
Phleum alpinum, *Shepherdia canadensis*, *Poa* sp., *Botrychium spathulatum* and *B. lunaria*. (~40 years)
Bridge and Parking Area

This small study represents a sample size of one and cannot be properly used to generalize about the behaviour of all moonworts, or even of other populations of the same species. It is one data point in a distribution. Some populations of moonworts may be able to establish themselves after glaciation more rapidly, while others, such as forest dwelling species like *Botrychium montanum*, may require thousands of years. This brief survey provides information about the comparatively rapid rate at which this particular mixed population was able to inhabit a recently deglaciated landscape. This also raises the possibility that moonworts were far more prevalent during the hypsithermal interval when receding glaciers were a more common feature of the North American landscape.

FUTURE WORK

South Drywood Creek is home to several of Alberta's rarest plants. J. Gould, T. Dolman, and D. Dolman visited the watershed in 1999, at which time collections were made of *B. lanceolatum* (S2), *B. lunaria* (S4S5), *B. pinnatum* (S1), *B. paradoxum* (S1), *B.* 'michiganense' (S1), *B. minganense* (S2S3), *B.* x *watertonense* (S1), *Papaver pygmaeum* (S2), and *Townsendia condensata* (S2). In 2001, I also found *B. campestre* (S1) and *Cryptogramma stelleri* (S2) in the valley (rankings follow Gould 2001). This watershed clearly contains a large number of significant species and yet, to date, a full botanical survey has not been completed. A thorough survey is strongly recommended and further investigations into the adjacent valleys of the Front Range are encouraged. The upper end of South Drywood Creek, with its many rare species, deserves recognition for its tremendous biological heritage.

Elk Island National Park contains a number of populations of rare *Botrychium* species. Among them is a plant that does not appear to fit into previously described taxa. This plant has been tentatively called *Botrychium* 'laciniatum', named after the narrowly divided pinnae. An intensive investigation, including isozyme or DNA analysis, is necessary to determine whether or not *Botrychium* 'laciniatum' is a distinct species.

In 1998, W.H. Wagner and F.S. Wagner issued a report to North American botanists to be on the lookout for *Botrychium boreale*, a species previously known from northern Europe and Asia, and from Greenland. Their report stemmed from two plants collected in the early 1980's in eastern British Columbia, close to the Alberta border. During the *Botrychium* Workshop in 1999, W. H. Wagner recognized this species among the plants growing at the Castle Junction Internment Camp site (CAS 1), in Banff National Park. In late 1999, after further study of the specimen, Wagner indicated uncertainty about the determination. In western North America there are three species that are pinnate-pinnatifid and which are quite similar to *B. boreale*. These three, *B. pinnatum*, *B. hesperium*, and *B.* 'michiganense', are themselves, sometimes difficult to tell apart. A small study using isozyme or DNA analysis should be conducted to determine whether specimens labeled '*Botrychium boreale*' from North America are related to those from Greenland, Europe, and Asia.

Botrychium boreale

Every year, new localities for rare Botrychium species are discovered. With the publication of "The Botrychiaceae of Alberta" and "Rare Vascular Plants of Alberta" it is hoped that inquisitive field biologists will fill some of the gaps in the distributions of these species. Three regions that should be considered priorities for future *Botrychium* surveys are Swan Hills, Lesser Slave Lake, and the Cypress Hills. A small number of historical collections have been made in the Swan Hills including *B. simplex*, *B. lunaria*, *B. minganense*, *Botrypus virginianus*, and *Sceptridium multifidum*, but few of these collections are recent. There have been few reports of *Botrychium* species in the Cypress Hills of Alberta (J. Gould pers. comm.). The numerous interesting collections from the Saskatchewan side of Cypress Hills suggest that it would be valuable to take a closer look at adjacent Alberta. It should be noted that June and July appear to be the best months for conducting surveys, particularly in drier years.

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Botrychium spathulatum

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Appendix A

	ELK 1	ELK 2	ELK 3	ELK 4	ELK 5	ELK 6	ELK 7	ELK 8	ELK 9	ELK 10	ELK 11	ELK 12
Botrychium sp.												
Botrychium ascendens		+										
Botrychium campestre												
Botrychium crenulatum *												
Botrychium hesperium *												
Botrychium 'laciniatum' **				+			+					
Botrychium lanceolatum	+											
Botrychium lunaria				+			+					
Botrychium 'michiganense'	+		+	+	+		+	+	+	+	+	+
Botrychium minganense		?		+								
Botrychium pallidum	+			+	+		+	+			+	+
Botrychium paradoxum *												
Botrychium pedunculosum *												
Botrychium pinnatum							+					
Botrychium simplex												+
Botrychium spathulatum												
Botrychium x *watertonense* *												
Botrypus virginianus				+	+							
Sceptridium multifidum	+			+		+	+			+		+
Elevation	820m	820m	820m	820m	820m	790m	790m	790m	790m	790m	790m	790m
Slope	2	2	5	0-10	0	1	5	0-5	5	5	0	0-10
Aspect	W	W	E	SE-SW	NA	NA	310	NA	NA	NA	NA	W
Moisture	submesic	submesic	submesic	submesic	submesic	subxeric	submesic	subxeric	xeric	xeric	submesic	subxeric
Date	6/10	6/10	6/10	6/10	6/10	8/4	6/11	6/11	6/11	6/11	6/11	6/11
Exposed soil	nd	nd	nd	nd	nd	10	40	nd	50	50	nd	nd
Vascular plant cover	nd	nd	nd	nd	nd	60	60	nd	50	50	nd	nd
Litter	nd	nd	nd	nd	nd	15	nd	nd	nd	nd	nd	nd
Moss cover	nd	nd	nd	nd	nd	5	nd	nd	nd	nd	nd	nd
Lichen cover	nd	nd	nd	nd	nd	70	nd	nd	nd	nd	nd	nd
Associated Species												
Fragaria virginiana	+	+				+	+	+			+	
Gentianella amarella	+	+				+		+				
Penstemon confertus												
Campanula rotundifolia						+	+					
Equisetum arvense	+	++		+	+							
Potentilla gracilis												
Achillea millefolium	+	+				+			+			
Allium cernuum												
Galium boreale									+			
Rhinanthus minor												

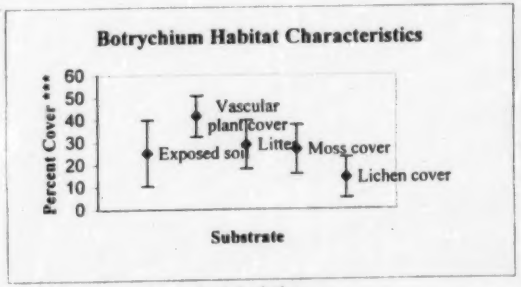
*** species that were not observed during this project**

**** a potentially undescribed species from Elk Island National Park**

nd= no data

NA= slope too low to make aspect ecologically significant

Percent cover estimates for associated species
+ present
++ 1-2%
+++ 3-10%
++++ 11-20%
+++++ >20%



*** Bars indicate standard deviation

Habitat Features	
Elevation	790-2100m
Slope	0-60%
Aspect	all aspects
Moisture	xeric-subhygric

Ranges of Cover Values	
Exposed soil	0-90%
Vascular Plant Cover	10-90%
Litter	5-65%
Moss	0-80%
Lichen	0-70%

	ELK 13	DRY 1	DRY 2	DRY 3	WAT 1	TRUNK 1	TRUNK 2	TRUNK 3	TRUNK 5	YAM	KAN 1	KAN 2
Botrychium sp.					+							
Botrychium ascendens							+		+			
Botrychium campestre			+							+		
Botrychium crenulatum *												
Botrychium hesperium *												
Botrychium 'laciniatum' **												
Botrychium lanceolatum	+			+		+						
Botrychium lunaria		+	+	+		+			+		+	+
Botrychium 'michiganense'	+											
Botrychium minganense			+	+							+	+
Botrychium pallidum	+											
Botrychium paradoxum *												
Botrychium pedunculosum *												
Botrychium pinnatum		+						+				
Botrychium simplex												
Botrychium spathulatum												
Botrychium x *watertonense* *												
Botrypus virginianus												
Sceptridium multifidum												
Elevation	790m	1800m	1800m	1800m	1500m	1500m	1500m	1675m	1500m	1370m	~1500m	~1500m
Slope	2	0	35	55	0	35	15	30	0	5	0	10
Aspect	NA	NA	360	260	NA	120	50	90	NA	180	NA	60
Moisture	submesic	subxeric	subxeric	subxeric	subxeric	subxeric	submesic	submesic	subxeric	xeric	subhygric	mesic
Date	6/11	8/6	8/6	8/6	8/5	8/8	8/8	8/8	8/8	8/9	8/9	8/9
Exposed soil	nd	5	10	50	0	20	30	10	0	80	0	10
Vascular plant cover	nd	90	40	10	15	75	25	50	50	15	50	50
Litter	nd	nd	50	20	5	65	10	20	50	10	60	50
Moss cover	nd	30	30	10	80	10	60	50	50	0	40	20
Lichen cover	nd	10	2	10	0	5	0	20	0	0	2	20
Fragaria virginiana	+++	+++		+		+++	+++	+++	++++		+++	
Gentiana amarella							+		+	+		
Penstemon confertus		++++		+		+++		+	++			++
Campanula rotundifolia						++				+		+
Equisetum arvense	+++						++	+				
Potentilla gracilis		++				++		+++	++	+		
Achillea millefolium	+	++		+		++			+		+	
Allium cernuum				+		+				+		
Galium boreale		++	+	+		+			+	+		
Rhinanthus minor						+	++					

	KAN 3	KAN 4	CAS 1	CAS 2	CAS 3	ICE 1	ICE 2	ICE 3	ICE 4	ICE 5	ICE 6	TOTAL
Botrychium sp.												1
Botrychium ascendens			+	+				?				5
Botrychium campestre												1
Botrychium crenulatum *												0
Botrychium hesperium *												0
Botrychium 'laciniatum' **												2
Botrychium lanceolatum					+							5
Botrychium lunaria	+	+	+			+	+		+	+	+	17
Botrychium 'michiganense'												11
Botrychium minganense	+	+							+			8
Botrychium pallidum												8
Botrychium paradoxum *												0
Botrychium pedunculosum *												0
Botrychium pinnatum							+					4
Botrychium simplex												1
Botrychium spathulatum						+	+			+	+	4
Botrychium x *watertonense* *												0
Botrypus virginianus												2
Sceptridium multifidum												6
Elevation	~1500m	~1500m	1500m	1675m	1800m	~1800m	~1800m	~1980m	~2100m	~1980m	~1980m	
Slope	10	0	0	10	20	60	2	5	5	10	2	
Aspect	120	NA	NA	240	~230	180	240	340	~45	90	NA	
Moisture	mesic	xeric	submesic	mesic	xeric	submesic	subxeric	subxeric	subxeric	submesic	xeric	
Date	8/9	8/9	8/10	8/10	8/10	8/11	8/11	8/11	8/11	8/12	8/12	
Exposed soil	0	5	0	10	60	30	5	90	10	60	80	
Vascular plant cover	50	40	50	40	40	40	60	10	70	35	20	
Litter	60	15	50	50	15	10	15	0	50	10	0	
Moss cover	30	35	20	5	0	50	40	0	30	15	0	
Lichen cover	30	45	30	5	0	10	40	2	10	10	0	
Fragaria virginiana	++++	+++		+++		++	+++		+	+		
Gentiana amarella			+	+	++		+	+		+		
Penstemon confertus			+		++							
Campanula rotundifolia					++							
Equisetum arvense						+						
Potentilla gracilis			+									
Achillea millefolium		+				+	++					
Allium cernuum												
Galium boreale												
Rhinanthus minor												

Appendix B

Sites	UTM	East	North	*Botrychium* sp.	*Botrychium ascendens*	*Botrychium campestre*	*Botrychium crenulatum*	*Botrychium hesperium*	*Botrychium 'lacinietum'*	*Botrychium lanceolatum*	*Botrychium lunaria*	*Botrychium 'michiganense'*	*Botrychium minganense*	*Botrychium pallidum*	*Botrychium paradoxum*	*Botrychium pedunculosum*	*Botrychium pinnatum*	*Botrychium simplex*	*Botrychium spathulatum*	*Botrychium x watertonense*	*Botrypus virginianus*	*Sceptridium multifidum*
ELK 1	12U	381535	5943669							+		+		+								+
ELK 2	12U	381472	5943701		+								?									
ELK 3	12U	381358	5943662									+										
ELK 4	12U	381110	5943668						+		+	+	+	+							+	+
ELK 5	12U	380754	5943397									+		+							+	
ELK 6	12U	380861	5946525																			+
ELK 7	12U	379889	5947145						+		+	+		+			+					+
ELK 8	12U	380858	5946466									+		+								
ELK 9	12U	380896	5946258									+										
ELK 10	12U	380708	5946083									+										+
ELK 11	12U	380560	5946220									+		+								
ELK 12	12U	380334	5946014									+		+				+				+
ELK 13	12U	380793	5945982							+		+		+								
DRY 1	11U	712023	5457825								+						+					
DRY 2	11U	712024	5457538			+					+		+									
DRY 3	11U	712042	5457442							+	+		+									
WAT 1	11U	716300	5446525	+																		
WAT 2	11U	716300	5446525																			
WAT 3	11U	716786	5445985																			
WAT 4	11U	716610	5446332																			
WAT 5	12U	296476	5438521																			
TRUNK 1	11U	681851	5505743							+	+											
TRUNK 2	11U	681503	5506911		+												+					
TRUNK 3	11U	681128	5514207																			
TRUNK 4	11U	685499	5523432																			
TRUNK 5	11U	678918	5561839		+						+											
YAM	11U	633059	5662503																			
KAN 1	11U	633366	5616416								+		+									

Sites	UTM	East	North	*Botrychium* sp.	*Botrychium ascendens*	*Botrychium campestre*	*Botrychium crenulatum*	*Botrychium hesperium*	*Botrychium 'lanceolatum'*	*Botrychium lanceolatum*	*Botrychium lunaria*	*Botrychium 'michiganense'*	*Botrychium minganense*	*Botrychium pallidum*	*Botrychium paradoxum*	*Botrychium pedunculosum*	*Botrychium pinnatum*	*Botrychium simplex*	*Botrychium spathulatum*	*Botrychium x watertonense*	*Botrypus virginianus*	*Sceptridium multifidum*
KAN 2	11U	633409	5616288								+		+									
KAN 3	11U	633469	5615969								+		+									
KAN 4	11U	633540	5611449								+		+									
CAS 1	11U	571895	5682356		+						+											
CAS 2	11U	571895	5683241		+																	
CAS 3	11U	573262	5683517							+												
ICE 1	11U	543811	5722374								+								+			
ICE 2	11U	536508	5727797								+						+		+			
ICE 3	11U	534320	5729154		?																	
ICE 4	11U	492204	5782093								+		+									
ICE 5	11U	491203	5782296								+								+			
ICE 6	11U	484149	5784353								+								+			
TOTAL				1	5	1	0	0	2	5	17	11	8	8	0	0	4	1	4	0	2	6